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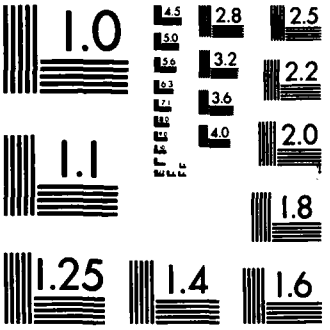

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ENVIRONMENTAL IMPACT RESEARCH PROGRAM

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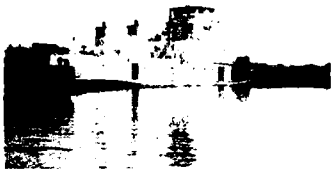
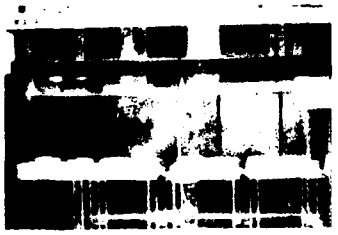
PHYSICAL EFFECTS OF COMMERCIAL NAVIGATION TRAFFIC IN LARGE WATERWAYS

SUMMARY OF A WORKSHOP HELD IN LOUISVILLE, KENTUCKY, 4 MARCH 1986





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August 1987
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A meeting was held on 4 March 1986 in Louisville, Ky., to discuss the results of recent studies and new research on the physical effects of navigation traffic in large waterways. The meeting was attended by representatives from the Illinois State Water Survey; the University of Maryland; the US Army Engineer Waterways Experiment Station (WES); the Navigation Planning Support Center of the US Army Engineer District, Louisville; the Office of the Chief of Engineers; and the following US Army Engineer Districts: Huntington, St. Paul, Detroit, and Mobile. Participants summarized the results of the following studies on navigation traffic: environmental effects of the Chesapeake and Delaware Ship Canal, field experiments on the physical effects of traffic, examination of the problems of ice in navigable waterways, navigation effects in the Tennessee-Tombigbee Waterway, habitat creation projects, and navigation effects on freshwater mussels. Participants suggested the following topical areas for future work: (1) water velocity and turbulence from movement of commercial vessels;

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(2) analysis of ice-related issues, including hydraulic conditions resulting from vessel passage, effects of ice under the hulls of commercial vessels, and scouring effects of ice following vessel passage; (3) sediment resuspension and ultimate redeposition due to propeller jet velocity and tow-induced waves; (4) channel border wave wash; and (5) water exchange between main channel and slack-water habitats caused by commercial traffic. This information has been used to aid in planning research studies on navigation effects being conducted by the WES and the Navigation Planning Support Center, US Army Engineer District, Louisville, Ky.

PREFACE

In October 1985, the US Army Engineer Waterways Experiment Station (WES) initiated a multiyear study of the environmental effects of navigation traffic in large waterways. This work is part of the Environmental Impact Research Program (EIRP) at the WES. This report summarizes the results of a workshop held on 4 March 1986 to discuss studies of towboat physical forces, part of the EIRP effort on navigation traffic. This report was written, edited, and reviewed by all attendees at the workshop. Dr. Andrew C. Miller, WES, and Mr. Terry Siemsen, Navigation Planning Support Center, were responsible for compiling and editing the completed document.

Navigation studies at the WES are under the general supervision of Drs. Thomas D. Wright, Chief, Aquatic Habitat Group; Conrad J. Kirby, Chief, Environmental Resources Division; and John Harrison, Chief, Environmental Laboratory. Dr. Roger T. Saucier is the Program Manager of the EIRP. This report was edited by Ms. Lee T. Byrne of the WES Information Products Division, Information Technology Laboratory.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

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CONTENTS

PHYSICAL EFFECTS OF COMMERCIAL NAVIGATION TRAFFIC IN LARGE WATERWAYS

PART I: INTRODUCTION

Background

1. In the 1970's and early 1980's, this country experienced an increased movement of bulk commodities by waterways. In addition, many existing locks, dams, and other navigation structures have had to be rehabilitated or replaced to increase efficiency and/or physical capacity. Important navigation projects underway by the US Army Corps of Engineers (CE) include the Lock and Dam 26 replacement project (US Army Engineer District (USAED), St. Louis), the Tennessee-Tombigbee Waterway (USAED, Mobile and Nashville), the Gallipolis Locks and Dam replacement project (USAED, Huntington), the Saint Marys River project (USAED, Detroit), and the Lower Ohio River project (USAED, Louisville). These studies have led to considerable concern on the part of many groups of the need to identify the physical and biological effects of increased commercial navigation traffic in large waterways.

2. In October 1985, the Office of the Chief of Engineers (OCE), US Army, funded the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., to conduct studies on the physical and biological effects of commercial navigation traffic on this Nation's inland waterways. The purposes of this research are to (a) provide data on the effects of physical changes brought about by commercial traffic, such as cyclic turbulence and turbidity on the growth, physical condition, and mortality of aquatic organisms; and (b) identify techniques to evaluate the physical and biological effects of commercial traffic. As part of this work, a meeting was held in Louisville, Ky., to review and investigate work to date regarding the most important physical effects of navigation traffic from the perspective of the CE. The meeting was attended by CE representatives and others (Table 1) who had specific experience with navigation-related issues. The purpose of the meeting was to review past research on the physical effects of navigation traffic and to suggest and evaluate future lines of research in this area. The results of this workshop will be used to direct the studies on navigation traffic being conducted by the WES.

Table 1

Attendees at a Workshop on the Environmental Effects of Commercial Navigation Traffic, 4 March 1986, Louisville, Kentucky

Name	Organization	Telephone No.
Andrew Miller	Waterways Exp. Station Vicksburg, MS	(601) 634-2141 FTS 542-2141
Terry Siemsen	Louisville District Office Navigation Planning Support Center (ORLPD-C) Louisville, KY	(502) 582-5550 FTS 352-5550
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Jack Killgore	Waterways Exp. Station Vicksburg, MS	(601) 634-3397 FTS 542-3397
Ray Morgan	University of Maryland Frostburg, MD	(301) 689-3115
Nani G. Bhowmik	Illinois State Water Survey Champaign, IL	(217) 333-0238
John Bushman	OCE Planning Division (DAEN-CWP-P) Washington, DC	(202) 272-0132
Mark Lisney	Louisville District Office Navigation Planning Support Center (ORLPD-C) Louisville, KY	(502) 582-5657 FTS 352-5657
Don Williams	Detroit District Office (NCEDP-EA) Detroit, MI	(313) 226-2225 FTS 226-2225
George Kincaid	Huntington District Office (ORHED-HW) Huntington, WV	(304) 529-5079 FTS 684-5079
Barry Payne	Waterways Exp. Station Vicksburg, MS	(601) 634-3837 FTS 542-3837
John Wright	Ohio River Division Office Cincinnati, OH	(513) 684-6206 FTS 684-6206

Purpose and Scope

3. The purpose of this paper is to present the results of the workshop on the physical effects of navigation traffic held on 4 March 1986 in Louisville, Ky.

PART II: CURRENT STUDIES ON PHYSICAL EFFECTS OF NAVIGATION TRAFFIC

Corps of Engineer District Offices

4. The first part of the workshop was devoted to reviewing ongoing and past studies on the physical effects of navigation conducted by the CE and other agencies. The following were discussed:

Detroit District

5. The concern of the USAED, Detroit, with navigation-related problems has risen from two studies. These are the Great Lakes Connecting Channels and Harbors Study and the Extended Season Navigation (i.e., Winter Navigation) Study.

6. Initial work on the environmental effects of navigation was conducted as part of the Winter Navigation Demonstration Program. This work involved an analysis of drawdown and surge of water levels with vessel passage. Studies of bank erosion and bank-erosion potential were also conducted, as were the effects of navigation on invertebrate drift.

7. As part of the Extended Season Navigation Study, the USAED, Detroit, hired contractors to develop mathematical models to assist in understanding drawdown, surge, and propeller wash effects (including backwater flow) of vessels operating in ice-covered channels. In these channels, wave forces are dampened by the ice so that the effects of drawdown and surge are more significant. Based upon field observations, vessel speed rather than the presence of ice appears to be the significant factor in causing negative environmental effects. The greatest effect appeared to occur in narrow channels. These models and associated reports are available in draft form. The information supplied and the models will allow a better estimate of the effects of ice on the physical impacts of navigation.

8. The USAED, Detroit, plans to include propeller wash, wave effects, and drawdown in a single model that will be used to evaluate the effect of ice on water velocities throughout channel cross sections. The District will calibrate this model using sites on the Saint Marys River, Michigan, and will use it at other sites in the Great Lakes and connecting channels to complete the Extended Season Navigation Environmental Impact Statement.

Mobile District

9. The USAED, Mobile, evaluates navigation impacts on inland waterways, coastal waterways, and small navigation projects. The Tennessee-Tombigbee Waterway (TTW) is an inland waterway that was well studied as part of the preparation of an Environmental Impact Statement (EIS) and supplement to the EIS. The study included monitoring results of previous construction to determine the impacts on physical and biological resources resulting from commercial traffic. The District has designed a series of Phase III (post-construction) Continuing Environmental Studies to be implemented on the TTW. The TTW is unique in that the navigation system is new, providing an opportunity to design experiments different from those that can be conducted on existing waterways. Aquatic habitats created as a result of construction can be monitored as navigation traffic increases. The design of the TTW allows for opportunities to analyze a variety of physical and biological conditions that are close to one another. For example, the lower Bay Springs Lake is 84 ft deep, whereas the upper end is a confined, uniform 280- by 12-ft channel. In the Divide Section, propeller jet-velocity effects, sediment suspension, and turbidity patterns can be evaluated.

10. Currently, the USAED, Mobile, is developing management strategies for selected bendways that were created on the TTW. Fish studies are being planned, gravel bar habitats for molluscs and fishes have been constructed, and there is an active water quality monitoring program. All of these projects will provide an evaluation of the effects of commercial navigation traffic in a newly constructed waterway.

11. As part of the development of the TTW, disposal methods for dredged material have been changed. Instead of within-bank disposal, material is being taken to upland diked areas. There are no data on the environmental effects of the dredging program associated with the TTW. More information on both physical and biological impacts is needed.

12. Navigation projects in coastal areas involve problems ranging from saltwater intrusion to dredged material disposal. For example, consideration is being given to deepening Mobile Harbor and Ship Channel to 55 ft. The effects of deep draft navigation traffic on the resources in a shallow bay can be determined by a well-designed monitoring program. The disposal of dredged material will affect water currents and benthic invertebrates. Sediment resuspension associated with commercial traffic in estuarine areas has not

been well studied. Overall, the planning of projects in coastal areas requires complex physical and biological data. The USAED, Mobile, is exploring innovative ways of predicting, measuring, and mitigating these impacts.

13. The USAED, Mobile, has numerous small navigation projects that involve abandoned (dead end) canals and channels. Degraded water quality and sediment resuspension are problems associated with these habitats. There is a need to study navigation impacts at small and large channels.

St. Paul District

14. Most USAED, St. Paul, field investigations on the Upper Mississippi River have been directed toward predicting the effects of channel maintenance actions and hydropower operation rather than the effects of vessel passage. Aerial photography of turbidity plumes caused by towboat passage during certain GREAT I water quality studies revealed that vessel passage caused significant resuspension of sediment in channel areas with fine-grained substrates. Erosion-prone shoreline areas were identified during the GREAT I studies, with the intention of preventing further habitat losses by shoreline stabilization.

15. The main channel border (MCB) in the Upper Mississippi River is a major habitat area that is subject to navigation effects because of its proximity to traffic using the main channel. A study of the MCB habitat in Pool 5A was conducted during 1981-1982. This study included a physical survey of the MCB in the entire pool (substrate survey, bathymetric survey, current velocity and direction). Habitat types were defined, and biological sampling was done to determine habitat associations of fish, macroinvertebrates, and aquatic macrophytes. These studies revealed that the MCB contains much of the hard substrate available in the river for filter-feeding invertebrates. The rock channel training structures and associated areas provide habitat for numerous species of fishes. The use of the MCB habitat types by fish and macroinvertebrates is governed to a large degree by current velocity, resulting in significant spatial and seasonal changes in relative abundance and species composition of these organisms. The work is summarized in two reports available through the USAED, St. Paul. These two reports are Anderson, Wilcox, and McConville (1983) and Siegert, Lewis, and Bockelman (1984).

16. Hydropower feasibility studies at Mississippi River Locks and Dams (L/D's) 5, 7, and 8 included quantification of ichthyoplankton drift and tailwater habitat in an effort to predict the effects of hydropower operation. Ichthyoplankton drift at L/D 5 was sampled for an entire season. Species

composition, life stages present, spatial distribution in the river cross section, diel variation, drift rate, and total quantity of drift were determined. The results of these studies are available through the USAED, St. Paul (Holland 1985). Tailwater habitat at L/D 8 was studied by surveying substrate type and bathymetry and then coupling these results with predictions of current velocity generated by a numerical hydraulic model (RMA-20). Physical habitat types were defined. The areal extent and distribution of these habitat types were modeled for existing conditions and with hydropower conditions over the full range of river discharge. Reports of this work are available through the USAED, St. Paul (Gee and Wilcox 1985).

17. A similar tailwater habitat study is underway at Mississippi River L/D 3. Physical changes to the dam approach to improve navigation safety are being analyzed because of possible alteration of tailwater habitat and a valuable sport fishery. Areal extent and distribution of habitat types will be modeled using depth, substrate, and current velocity. A hydroacoustic survey of fish distribution will be conducted by research biologists from the WES. Analysis of habitat association data for fish observed by hydroacoustic equipment should reveal which physical habitats are most important to fish staging in the tailwater at L/D 3.

18. Proposals for port facility expansion and increase in traffic levels on the East Channel at Prairie du Chien, Wis., have caused concern about traffic effects on the mussel resource in the East Channel, particularly the endangered *Lampsilis higginsi*. An interagency monitoring effort, coupled with quantitative mussel sampling by WES research biologists, will provide a long-term data set on the effects of increasing traffic on river habitats and the mussel community. A physical habitat survey, traffic monitoring, and study of mussel population characteristics are under way. Future plans include long-term monitoring of mussel populations, use of a numerical hydraulic model to predict flow patterns and velocities, measurement of the extent of turbidity/suspended solid plumes generated by towboats, and a mussel distribution survey. Preliminary results are reported in publications available through the WES.*

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* A. C. Miller, B. S. Payne, and P. D. Hartfield. 1984. "A Mussel Study at Prairie du chien, Wisconsin, 1-4 October 1984," letter report submitted to the US Army Engineer District, St. Paul, St. Paul, Minn.

Huntington District

19. Physical effects studies were initiated in response to a need for greater understanding of the physical effects of commercial navigation traffic. Results of these studies will soon be available.

Illinois State Water Survey Division

20. The Illinois State Water Survey Division is involved in the investigation of the physical impacts of navigation. The major objective of these studies is to determine the physical impacts of navigation traffic on sediment resuspension, waves, and water exchange with side channels. Sponsors for this work include the Upper Mississippi River Basin Commission and the National Science Foundation (NSF). Research was conducted on a variety of topics for 2 years, and a number of research reports were prepared. Presently, the Illinois State Water Survey, Illinois Natural History Survey, Illinois State Geological Survey, and Western Illinois University are involved in a research project on Pool 19 and Pool 26 of the Mississippi River and the Peoria Pool of the Illinois River. This work is partially supported by NSF and is called LTER. This study, now in its fifth year, is in the process of preparing proposals for the next 4 years.

21. Major findings of these studies are: (a) barge and tows on the Mississippi and Illinois rivers resuspend sediment; (b) the elevated core (level) of resuspended sediments can last up to 90 min; (c) successive tow passage can increase the ambient sediment core (these navigation impacts will be most noticeable on shallow, confined waterways such as the Illinois River rather than the Mississippi River); (d) wind and river-traffic generated waves can and will have significant effect on bank line erosion; and (e) drawdown is a significant impact in shallow border areas.

Shear Stress Studies on the Chesapeake and Delaware Canal Project

22. The USAED, Philadelphia, sponsored a comprehensive program from 1970 to 1974 to investigate the hydrographic and biological effects of widening the Chesapeake and Delaware (C&D) Canal, a major link between the Delaware River and the Upper Chesapeake Bay. Congress authorized the widening and deepening of the C&D in 1954 as well as establishing a research program for

assessment of effects. The research program was divided among three universities: Chesapeake Bay Institute of the John Hopkins University, Chesapeake Biological Laboratory of the University of Maryland, and the College of Marine Studies of the University of Delaware. The Chesapeake Biological Laboratory was responsible for an ichthyoplankton program, a benthic program in Maryland waters of the C&D Canal, an adult-finfish program, and a program to determine environmental impacts on fish eggs and larvae. The direction of the last program was to determine the effects of: (a) possible temperature salinity changes on dominant ichthyoplankton species, (b) suspended sediment levels on the same species, (c) water quality throughout the C&D Canal, and (d) the passage of ships through the canal.

23. The objectives of these studies were to determine possible environmental impacts on fish eggs and larvae due to the C&D Canal enlargement that was mandated by Congress (Committee on Public Works, 1970, The Chesapeake and Delaware Canal Hearings (91-32), House of Representatives).

24. Major findings of the research include the following:

a. The water quality of the east end of the C&D Canal and the Delaware River caused higher larval and egg mortalities in striped bass than did the water quality of the western end of the canal. Possible changes in temperature/salinity profiles in the major spawning areas on the west end of the C&D Canal would not cause major problems for successful hatch of striped bass and white perch. However, a major change in the temperature/salinity profiles would possibly shift the site of spawning farther to the eastern part of the canal.

b. High levels of suspended sediment did not affect hatch of fish eggs, but increasing levels of sediment slowed the rate of development.

c. Shear stress from navigation traffic did not significantly impact the ichthyoplankton populations in the C&D Canal. Shear stress associated with hulls were calculated and tended to be lower than shear levels required to kill eggs or larvae.

Navigation Planning Support Center

25. The Navigation Planning Support Center, USAED, Louisville, has been delegated the responsibility of developing a method to determine the environmental effects of commercial navigation traffic for the inland navigation system within the Ohio River Basin. The intent of the program is to develop:

a. Generally accepted methods such that the environmental effects of navigation traffic can be predicted and quantified for feasibility level studies.

b. Generally accepted methods such that the environmental effects of continued operation and maintenance of navigation structures and systems can be predicted and quantified.

c. Measures that could be undertaken by the CE or others to minimize potential adverse ecological effects and would maintain or enhance the environmental quality of navigable waterways.

26. The intent of the program is to develop a means whereby the relative effects of alternative scenarios of commercial navigation traffic can be assessed. The method must provide a numerical rating rather than a subjective quality assessment to enable quantitative measurement of the amount of mitigation recommended.

27. Developmental activities have proceeded along several avenues. Efforts are under way to better quantify the magnitude of the forces created by tows under operation. These forces are the causative factors of most biological effects and must be clearly understood. The WES will be conducting specific tests of the effects of periodic increases in turbidity and/or turbulence on target organisms. The Ecological Services Office of the US Fish and Wildlife Service, Cookeville, Tenn., will assist in the development of models that are patterned on Habitat Suitability Index models and that will reflect the effects of tow forces on the life requisites of aquatic organisms. The final step will be to combine these various efforts into a software system to allow a numeric analysis of an array of project alternatives.

US Army Engineer Waterways Experiment Station

Questions concerning effects of navigation traffic

28. CE biologists, engineers, and planners ask two types of questions concerning the effects of navigation traffic. The first pertains to physical effects and relates to the length of time that suspended solids remain in the water column or to the extent of water velocity changes at the substrate. The second question concerns the biological consequences of these physical effects. There is a need to know how turbulence or elevated suspended solids (which could be repeated 12 or 15 times per day) can affect growth or

mortality of aquatic organisms such as clams, macroinvertebrates, and fish larvae.

Research design

29. Navigation-related problems are difficult to study since they consist of a short, often repeated physical perturbation. Navigation effects do not cause major habitat changes like impounding a river, channelizing a stream, or dredging a river. For this reason, research on navigation traffic at the WES has been designed to first determine how selected physical effects (cyclic turbulence and turbidity, for example) influence mortality or the physical condition of representative aquatic species. The results of these studies can be used directly, or, as appropriate, they can be used to construct Suitability Index (SI) curves for habitat-based techniques such as the Habitat Evaluation Procedures.

30. This research is being accomplished through a series of tasks designed to investigate the physical effects of commercial traffic and the biological consequences of these perturbations. The major tasks for this study are:

a. Physical effects studies. The purpose of this task is to identify the magnitude and duration of physical change (elevated suspended solids, changes in water velocity, etc.) at representative habitats in large waterways. This information can be used by CE personnel and others to describe the type of physical changes likely to occur as a result of movement of commercial vessels. In addition, these data will aid in the design and execution of the laboratory and field studies on biological effects.

b. Laboratory simulation studies. Cyclic suspended solids or water velocity changes will be created in experimental chambers that mimic field conditions caused by commercial traffic. This task will provide data on the tolerances of representative aquatic species to perturbations caused by traffic. Information can be used to describe effects directly or to prepare SI models for based methods.

c. Biological field studies. Field studies of mortality, growth rates, or physical condition of organisms will be conducted at representative sites in navigable waterways. These studies will be designed to obtain data on specific attributes of naturally occurring individuals (physical condition, growth rates) and populations (size demographics, mortality) exposed to the physical effects of traffic.

31. The results of these studies can be used to establish the extent and magnitude of physical and biological effects of commercial navigation

traffic. Output from this work will consist of (a) quantitative data that define the extent of physical and biological alteration associated with traffic, (b) SI curves that can be used to evaluate certain aspects of navigation traffic using habitat-based methods, and (c) identification of field and laboratory methods to analyze environmental effects of movement of commercial navigation traffic in large waterways.

PART III: PROPOSED RESEARCH ON PHYSICAL EFFECTS OF NAVIGATION TRAFFIC

Background

32. The major objective of the workshop was to identify important research tasks that directly pertain to the physical effects of commercial navigation traffic (Table 2). Tasks were identified by group interaction and discussion. Descriptions of each task were prepared by individuals knowledgeable in each topical area; then, these descriptions were reviewed and edited by the group. The workshop participants identified major habitat types of concern in large rivers (Table 3) and listed significant sites where commercial navigation traffic studies have been conducted (Table 4).

Description of Tasks

Task 1: propeller-induced turbulence

33. Background. Only limited theoretical assessments of propeller jet and other tow-traffic effects are available. Field data that can be used to

Table 2

Research Topics on Physical Effects of Navigation Traffic
Identified and Discussed During the Workshop Held
in Louisville, Kentucky, 4 March 1986*

Task	Description
1	Propeller-induced turbulence
2	Fixed boat survey
3	Effects of traffic under ice conditions
4	Effects of ice buildup on barge hulls
5	Effects of ice fragmented by vessel passage
6	Sediment resuspension and deposition
7	Wave wash in shallow channel borders
8	Water exchange between main channels and side channels

* See text for further discussion of these topics.

Table 3

Major Habitat Types in Large Waterways

Side channel
Main channel
Main channel border
Slough, backwater, bendway
Tailwater
Embayment removed from the main channel

Table 4

Major Sites in Large Waterways Where Extensive Navigation Traffic Studies Have Been Conducted

River	Location
Mississippi	Prairie du Chien, Wis.
Mississippi	Pool 19, Ill.
Mississippi	Pool 5a, Winona, Minn.
Mississippi	Tailwater of Lock and Dam 3, Redwing, Minn.
Mississippi	Tailwater of Lock and Dam 8, Genoa, Wis.
Ohio	Olmsted, Ill.
Ohio	Gallipolis Locks and Dam
Illinois	Peoria, Ill.
Kanawha	Winfield Locks and Dam
Saint Marys	Lake Nicolet, Mich.
Tennessee-Tombigbee Waterway	Divide Cut, in Miss.
Tennessee-Tombigbee Waterway	Bay Springs Lock, Miss.

verify theoretical equations are scarce. Additional data are needed to evaluate the accuracy of existing models, to extend their applicability, and to improve the credibility of effects (impacts) assessed by the predictive equations.

34. Objectives. Existing models and variables are critically evaluated to predict propeller jet velocities. As necessary, field investigations are performed to confirm and/or adjust existing models or equations.

35. Approach. All existing models and data are reviewed, and key variables and the applicability of the various approaches are identified. Field sites and methods are selected to determine propeller jet velocities at specific distances from the sailing line as a result of commercial tow passage.

36. Why research and development are needed. The physical impacts of tow traffic, propeller wash, replacement flows, and waves are of paramount importance for predicting the biological consequences of existing and future traffic levels. Results of these studies can be used for the design of laboratory simulation experiments.

Task 2: fixed boat survey

37. Background. It is assumed that propeller jet velocity is the single greatest physical impact of a towboat. Existing mathematical equations for propeller velocity are for a tow in a fixed position; therefore, it seems reasonable to verify these equations in the condition for which they were developed.

38. Objectives. Two objectives of a fixed boat survey are to:
(a) measure water velocities at selected points behind a tow to provide a statistical basis to calibrate (verify) the available equations and
(b) empirically determine decay of tow-induced water velocities at specific depths in addition to the river bottom.

39. Approach. The study site should be relatively deep, still, and unaffected by ambient currents. At least two sizes of towboats (small and large horsepower) and at least two RPM settings per boat should be used for this work. Velocity measurements should be taken with flow meters at a number of X distances directly behind the tow, at a number of Y distances off the center line of the tow at each X distance, at depths equal to 0.2, 0.6, and 0.8 of water depth, and at the river bottom. Consideration should be given also to measuring pressures in the two axes simultaneously. This would

require a single season effort of about 4 to 5 days per towboat. Manpower is estimated to require four individuals for each day.

40. Why research and development are needed. There have been few verification studies of propeller jet velocity distribution under field conditions. This physical action is one of the most significant physical effects of commercial navigation traffic because of the potential effects on substrate and aquatic biota.

Task 3: effects of traffic under ice conditions

41. Background. There is almost no information on the effects of ice on forces generated by commercial traffic. Vessels traveling through an ice-covered channel encounter difficulties in maintaining the same speeds they would in open-water conditions. They use more power, which causes a higher propeller thrust. The resistance from ice depends on whether the cover is plate, brash, or refrozen ice. The thickness of the ice is a major concern because it resists vessel passage and it reduces channel cross section.

42. Objectives. Velocities and pressures are measured at critical points across several channels with ice cover as vessels pass. Changes in suspended solids induced by the event are coincidentally measured. Vessel information is obtained on speed, draft, propeller type, beam, and length. If possible, the field experiment is conducted in open water, in ice of various thicknesses, and in various conditions (such as recently broken or completely refrozen ice). Complete data on the cross section, shape, and the composition of sediments should also be available. If possible, a small and a large river cross section should be studied. Also, a ship site (such as Saint Marys River) and a tow site (such as Upper Mississippi River) should be selected.

43. Why research and development are needed. The results of this study would be used to prepare Environmental Impact Assessments and Environmental Impact Statements. These data would be useful for calibrating existing vessel passage models. In addition, the information from this work would be useful for providing general information on the effects of navigation under ice conditions in a large river habitat.

Task 4: effects of ice buildup on barge hulls

44. Background. Towboat pilots report more frequent groundings and "bumping" of lock sills during late and early season ice conditions.

Apparently, ice accumulates on barge hulls to the extent that draft is increased by a foot or more, which can result in direct disturbance of river substrate, more displacement flow, more frequent groundings, and associated prop scour. There is little, if any, literature on this subject.

45. Objectives. The objectives are to determine conditions that cause ice buildup on barge hulls, find ways to reduce it, and minimize adverse effects on the river system.

46. Approach. Conditions that contribute to ice buildup on barge hulls are determined. The frazil ice phenomena are investigated, and the actual thickness of ice accumulation on barge hulls is measured.

47. Why research and development are needed. There is much controversy about the environmental effects of early and late season navigation on the Upper Mississippi River. Ice buildup on barge hulls during this time potentially concerns safety and creates economic and environmental problems. The results of this work will provide data to aid in the assessment of the environmental effects of navigation traffic during the winter.

Task 5: effects of ice fragmented by vessel passage

48. Background. Towboat propellers grind pan ice into small fragments, which can induce ice formation in the jet zone during cold weather. Ice fragments accumulate at the lower end of pools and can affect habitat conditions. The ice fragments can act as abrasive particles, magnifying propeller jet scouring of the streambed. There is little literature on this subject.

49. Objectives. Conditions that result in large accumulations of fragmented ice are determined, and their effects on aquatic habitat are evaluated. It is determined if ice fragments magnify scouring from propeller jets. Ways to minimize adverse effects to riverine biota are identified.

50. Approach. Fragmented ice accumulation under pan ice is measured. The degree of propeller jet scouring is compared with and without ice fragments.

51. Why research and development are needed. There is controversy about the environmental effects of early and late season navigation on the Upper Mississippi River. The results of this work will aid in identification of the environmental effects of late season navigation.

Task 6: sediment
resuspension and deposition

52. Background. Commercial navigation traffic resuspends sediments from propeller-induced turbulence and wave formation. The magnitude of resuspension, deposition, and lateral transport is dependent on factors such as hydraulic and morphometric features of the river, particle size, and type and operation of a vessel. In order to determine the biological consequences of resuspension and deposition, information must be available on the magnitude and duration of these physical events in navigable waterways.

53. Objectives. This study will determine the effects of navigation traffic on the extent of sediment resuspension and deposition and the size of the distribution and the composition of these particles.

54. Approach. Three sites should be delineated for study: the main channel, side channel, and shoreline or backwater. Replicate measurements of water depth, current velocity, turbidity, total suspended solids, particle-size distribution, and inorganic/organic content of sediment particles should be made at each site before, during, and after barge passage. In addition, vessel specifications, distance measurements, and operating characteristics should be recorded. These data would indicate the magnitude and duration of resuspended organic and inorganic sediments at various distances from the vessels.

55. Sediment traps should be placed at three locations along a transect extending from the main navigation channel to the shoreline before barge passage. Three traps would be removed every 15 min at each location up to 1 hr after barge passage to determine settling rates and total deposition at various distances from the tow. A crew of three with a suitable vessel would be required to conduct this study. In addition, two divers would be used to place and retrieve the traps. This study would continue for a week in order to determine the effect of various types of tows on resuspension and deposition.

56. Why research and development are needed. Available information indicates that tow traffic increases suspended sediment levels. It is not known how the resuspension of material impacts the aquatic biota. Research is needed to quantify the relative magnitude of resuspension of sediment in waterways.

Task 7: wave wash in shallow channel borders

57. Background. The immediate nearshore zone is of concern for a variety of reasons. Studies of tow traffic have been concentrated on in-channel habitats or areas near the shoreline. The zone between a water depth of 1 to 2 m and the point of maximum water elevation has not been fully investigated. Shoaling and breaking of waves can generate relatively high velocities that have significant negative effects on biota and sediments.

58. Objective. The objective of this phase of the work is to measure the energy-exchange mechanisms associated with wave phenomena (height, duration, frequency, direction, etc.) in the zone between a water depth of 1 to 2 m and the point of maximum water elevation.

59. Approach. Important site-specific considerations include bank slope, sediment characteristics, sediment gradation, wave characteristics, and orientation and geometry of the waterway.

60. Why research and development are needed. Very little data are available for assessing energy-exchange mechanisms in the immediate nearshore zone. Until procedures are developed and data collected, it will not be possible to separate natural from tow-induced effects.

Task 8: Water exchange between main channels and side channels

61. Background. It has been shown that drawdown can cause the movement of masses of water into and out of wetland and side channels. Embayments and other backwater areas are known to be important with respect to fish spawning. Resource agencies have expressed concern on the effects of tow traffic in causing the exchange of water between backwater areas and the river and inducing enhanced turbidity and velocity levels.

62. Approach. This study could involve the following: (a) detrital loss, (b) sediment transport, (c) loss of larval fish and macrobenthos, and (d) changes in the type of organic material in the water. Movement of these materials could be studied using sediment traps, drift nets for invertebrates, and velocity meters.

63. Why research and development are needed. The embayments and side channels are the most productive portions in a large river system. Currently, there are few quantitative data on the effects of commercial navigation traffic on these habitats.

PART IV: SUMMARY

64. The workshop included both CE and non-CE experts to identify and discuss significant physical forces and resultant environmental impacts from navigation traffic. The group identified generic and specific study needs based upon their experience. The purpose of this workshop was to provide direction for a research program to study problems and needs associated with physical disturbance caused by navigation traffic. The program developed by the WES will further the abilities of biologists and engineers to predict physical and biological impacts associated with navigation traffic.

65. Navigation traffic on inland waterways will continue to expand along with population increases and the mobility of industrial society. The present navigation system is experiencing capacity strains resulting in the need for major expansion and rehabilitation or replacement of navigation structures. Environmental legislation is dictating an increased awareness of the environmental consequences of water resource development.

66. The need to expand navigation capability of inland waterways in the present legal environment requires extensive development of tools to measure environmental impacts. In order to develop those tools, the identification of major impacts and research to characterize them is required. Within the CE, separate organizational elements have been working on this problem for several years. To aid in the development of a comprehensive research program on navigation traffic effects, this workshop was convened.

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